APPLICATION

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TITLE: CYBERSPACE DATA MONITORING SYSTEM

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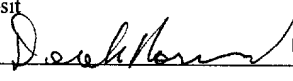
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MONITORING AND ANALYSIS OF DATA IN CYBERSPACE

ORIGIN OF INVENTION

5   The invention described herein was made in the performance of work under a NASA contract, and is subject to the provisions of Public Law 96-517 (35 USC 202) in which the Contractor has elected to retain title.

FIELD OF THE INVENTION

10   This invention relates to a data monitoring and analysis system. More specifically, the present invention defines a user interface providing a three dimensional representation of complex data, data relationships and system status.

BACKGROUND AND SUMMARY OF THE INVENTION

15

The operation of many complex systems requires an operator to monitor status of the system by assimilating a large amount of real-time status data received from various system components. Complex systems of this type include

20   spacecraft operations, industrial plants, financial trading activities, and hospital monitoring of medical data from patients. All of these systems require important decisions to be made, sometimes quickly, in response to a myriad of

data. Once the status of the system or the nature of a

problem is understood, the system operator takes appropriate

actions to implement decisions or to remedy the problem. In

extreme cases, these actions may save the system from

5   serious undesirable consequences. It is very important that

this complex data be presented clearly and concisely so that

the operator can obtain any information needed for

diagnostic purposes as easily and quickly as possible.

Existing data display systems often use numerical or

10   two-dimensional displays which require the operator to

interpret and analyze the data and its relationship to other

data. Some of the features of these kinds of displays are

illustrated in Figures 1a-1c, which graphically illustrate

how the composition of total information conveyed to a user

15   varies over time for various interface types. The total

information conveyed in these graphs is equal to the amount

of "navigation data" plus the amount of "destination data".

Navigation data is defined as that class of information that

orients a user in time, space, location and direction;

20   informs the user of progress in relative and/or absolute

terms; and that contains addresses, instruction to proceed,

and/or warnings not to proceed. Destination data is defined

as that class of information that satisfies the user's

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desire for information, for example, by answering a question.

Typically, the goal of a user interface is to maximize the volume of available destination data while

5   minimizing the delay in making the destination data available. As shown in Figure 1a, an operator of a command-driven interface has very little destination data available initially and spends roughly half of the time traversing alphanumeric menus ("navigation data") to get to the desired

10   data display ("destination data").

An operator of a menu-driven interface (Figure 1b) typically can access a larger volume of destination data somewhat faster after first navigating through one or more menu items. However, the operator can become frustrated

15   upon encountering several layers of sub-menus before being able to access the bulk of the destination data. This results in a drop-off (at time D in Figure 1b) in the amount of available destination data.

In a graphical user interface ("GUI"), the operator

20   traverses through various windows and screens to get at the destination data in a step-wise fashion as illustrated in Figure 1c. Certain destination data may not be accessible until the operator has stepped through a number of windows,

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thus diminishing the operator's efficiency. These graphs were presented by Michael Benedikt in the article "Cyberspace: Some Proposals" which appears in the book Cyberspace: First Steps.

5   These shortcomings of command, menu and GUI driven interfaces are magnified in data intensive operational environments of the kind described above. The inventors recognized a need in these environments for an improved user interface that makes more information available in less
10   time. Destination data is one example of such data. These problems are well illustrated in the example of spacecraft operation control.

During a typical spacecraft mission, data parameters from many different domains are monitored and/or analyzed in
15   real time to ensure that the spacecraft and its instruments are working properly. A mission control site receives this data from the spacecraft by telemetry. In this setting high volumes of data are received at very frequent intervals. Monitoring this data poses a daunting and complex challenge.
20   This is especially true when multiple spacecraft missions are being monitored simultaneously by a single system.

Early spacecraft data monitoring systems employed a panel of discrete, hardwired lights, each light

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corresponding to an individual data parameter. A team of
human operators (e.g., flight controllers or analysts)
monitoring the spacecraft mission, would continually observe
the various lights to ensure that the spacecraft and its
5   instruments were operating properly. A trained operator
could readily determine whether error or alarm conditions
were present simply by scanning the panel for the
appropriate color light. For example, a green light might
mean that a particular data parameter was within normal
10   ranges, while a red light might indicate that acceptable
levels for that parameter had been exceeded. The lights
provided a dramatic and immediately comprehensible
indication of system status. This early light-panel
monitoring system hence had the advantage of providing the
15   operator with an intuitive sense of system health.

As spacecraft and their associated instruments
became more sophisticated, light-panel monitoring systems
became inadequate to handle the volume and complexity of the
telemetry data that was being collected. Light-panel
20   systems also were difficult and labor-intensive to adapt for
new types of telemetry data that changed with each mission.

The next generation of data monitoring systems
attempted to solve this problem. A computer system (for

example, a work station) received telemetry data and displayed it in textual (*i.e.*, alphanumeric) form on the display monitor. Figure 2 shows a sample output of a typical text-based data monitoring system. The necessarily

5 high volume of telemetry data causes the display screen to become cluttered and difficult to read. An operator relying on the text-based monitoring system in Figure 2 is required to study and understand large amounts of alphanumeric information to accurately monitor the health of spacecraft.

10 That task requires extensive training and considerable diligence on the operator's part. Even with sufficient training, using a text-based system to monitor data is fatiguing for the operator and frequently results in missed alarm conditions or slow responses to alarm conditions.

15 In short, text-based data monitoring systems do not generate easily recognizable indicators of changes in system status. Rather, a change in system status (even a potentially catastrophic one) is signalled merely by changing one or more alphanumeric characters to other

20 lphanumeric characters on a display screen. The screen typically contains several hundred such alphanumeric characters, and even the most vigilant human operator can occasionally overlook an important alarm condition. Thus,

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there is a need for a system that can present a large amount of information to a user in a way that is readily understandable and in a way that conveys important conditions in a very noticeable way.

5   The data monitoring system of the present invention uses a three dimensional simulated space representation, (sometimes called a "cyberspace representation,"), to interface with, and to communicate complex, real-time information to an operator. A cyberspace representation

10   utilizes various elements (e.g., time, space, sound, travel, and user presence in the computer environment) to convey information to the operator. The root word "cyber" comes from the Greek word "kybernan" which means "to steer or control." Literally, cyberspace means to steer or control

15   space.

The cyberspace data monitoring system of the present invention may be implemented in conjunction with artificial reality or virtual reality systems. The cyberspace interface of the invention provides a graphically-oriented

20   user interface where the operator is figuratively positioned within the user interface environment. The invention uses a visual representation to communicate information to the user. The interface appears to the user as a perspective

view of a three-dimensional space from a particular vantage point. The user may move around within the three dimensional space, and thus change his view through manipulation of a cursor input device. As the user

5 navigates through the three-dimensional space, the display changes to reflect the operator's new position within the space. This movement may reveal objects that were not previously visible from the operator's prior vantage point.

The use of this cyberspace representation allows the

10 present data monitoring system to realize a "textless" or "minimal text" display that allows a human operator to assimilate and comprehend large quantities of data at a rate and to a degree much greater than previously possible. This is because the user interface of the invention is in a form

15 similar to that used to comprehend real-world events. Rather than representing information in the form of multiple rows and columns of alphanumeric characters, data is depicted in the form of graphic symbols or objects which are positioned within a three-dimensional virtual universe. The

20 respective dimensions of the virtual universe correspond to categories of information from various domains. For example, in one embodiment of the invention, these categories may include: the various spacecraft missions

being monitored, various user-defined categories of data

parameters that are relevant to the application, attitude

control system, propulsion, Alarm Log and User-Defined.

The Alarm Log category records all anomalous data values

5   until they are acknowledged by the user. The User-Defined

category allows copies of data values from any other

category to be grouped together. A third dimension may

correspond to certain user-defined alarm limits of state

value for each of the data parameter categories.

10   The shape, motion, position, color and behavior of

the graphic symbols are configured to convey an extensive

amount of information about the current values of the data

parameters to the human operator in an easily understandable

and instantly recognizable manner.

15   Figure 1d shows the Total Information to User graph

for a cyberspace-driven interface. A cyberspace-driven

interface does not require an operator to enter alphanumeric

commands or to traverse menu items or windows before

destination data is available. Rather, as illustrated in

20 Figure 1d by the three exemplary curves of cyberspace-driven

interfaces, the operator has essentially instantaneous

access to a considerable amount of destination data. This

results in a greater amount of usable information being

conveyed to the operator in less time.

Another advantage provided by the cyberspace-driven

system of the invention is that its visual abstraction of

5   data allows an operator to assess the qualitative status of

the various spacecraft with not much more than a mere glance

at the display screen. For example, in one embodiment of

the cyberspace system of the invention, information about

alarm severity is conveyed by the height of a pole extending

10   from the graphical objects. In a text-based system, in

contrast, severity information may be obtained only by

manually referring to the alphanumeric alarm limits of the

parameters of interest.

The cyberspace system also permits more data to be

15   displayed on the screen at any one time. Only a part of one

screen is used in the cyberspace system (in contrast to the

multiple screens that are used for text-based systems),

hence all of the telemetry data for an entire system can be

displayed unambiguously in a fraction of the screen real-

20   estate that has been previously required.

Yet another advantage of the cyberspace data

monitoring system is that it allows multiple systems to be

monitored simultaneously, and further allows related data

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parameters to be grouped (and re-grouped) by the operator

logically in space. Thus, the cyberspace system is easily

tailored to the specific needs of a particular system or to

the preferences of a particular operator.

5   Standard computer graphics manipulation techniques

are used to facilitate navigation through this virtual

universe of data to alter the relative vantage point within

the universe. Hence the operator may move between different

monitored systems (such as different spacecraft missions) to

10 inspect a particular data parameter or group of parameters

in more detail than might be possible at a different vantage

point within the universe.

The cyberspace data representation provided by the

invention eliminates the need for an operator to read large

15 volumes of textual material in order to determine system

status. Rather, merely by scanning the attributes of the

graphic symbols displayed on the screen, an operator gleans

an intuitive understanding of the system status that extends

far beyond the knowledge that could be imparted by a visual

20 inspection of either a light-panel display or a text-based

display.

Other advantages of the cyberspace data monitoring

system include the following: an operator is able to

recognize impending alarm conditions earlier and with greater reliability due to the intuitive nature of the cyberspace interface; operators may be trained faster and with greater efficiency; a plurality of sub-systems can be

5   operated as a single system instead of as collections of sub-systems because the status of the entire system can be understood from one display; fewer operators may be required by enabling a single operator to effectively monitor larger components of a system; operators can become aware of

10   problem situations before actual alarms occur and without needing to manually assess collected trend data; and operations differences between non-identical systems can be minimized.

BRIEF DESCRIPTION OF THE DRAWINGS

15   These and other features and advantages of the present invention will become evident from the detailed description set forth hereafter with reference to the accompanying drawings.

        Figures 1a-1d are graphs of Total Information to

20   User versus Time for various interface types.

        Figure 2 is a screen display from a text-based data monitoring system;

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Figure 3 is a block diagram of a preferred embodiment of the cyberspace data monitoring system of the present invention;

Figure 4 is a screen display from the cyberspace

5 data monitoring system of Figure 3;

Figure 5a is a screen display of the overview window in the cyberspace data monitoring system of the present invention;

Figure 5b is a screen display of the main window in

10 the cyberspace data monitoring system of the present invention;

Figure 6 is a screen display from the cyberspace data monitoring system of the present invention;

Figure 7 is a screen display from the cyberspace

15 data monitoring system of the present invention;

Figure 8 is a pop-up display from the cyberspace data monitoring system of the present invention;

Figure 9 is a screen display of the alarm suppression facility of the present invention;

20 Figure 10 is a screen display of a suppressed object in accordance with the present invention; and

Figure 11 is a flowchart of the method of one embodiment of the invention.

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DETAILED DESCRIPTION

Figure 3 shows a preferred embodiment of the cyberspace data monitoring system (CDMS) 10 of the present invention. The CDMS 10 has special features which

5   facilitate monitoring and control of one or more complex monitored systems 14, 16 and 18 by an operator. The operator may be required to quickly assess the real-time status of the monitored systems 14-18 and to make appropriate decisions regarding necessary responses to the

10   system status.

Data from the monitored systems 14-18 is processed by a conventional host computer 20 which includes a CPU 22, memory 24 and IO unit 26. Host 20 may preferably comprise a UNIX or PC workstation. The host 20 also includes a

15   cyberspace user interface 28 which contains the necessary computer programs and/or operating systems operating to implement the techniques of the invention. A transmitting unit such as a modem 29 is optionally employed for notifying an operator of a situation by means such as paging, in

20   addition to a visual display.

The cyberspace user interface 28 receives monitored system data under control of the CPU 22 and organizes and configures this information for display in

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accordance with the teachings of the present invention.   In

particular, the cyberspace user interface 28 controls a user

interface module 30 containing a display unit such as a CRT

32 and one or more input devices (keyboard, mouse, etc.) 34.

5   The input devices 34 are controlled by the user in response

to the information on the display unit 32.   This response is

then transferred to the cyberspace user interface 28 for

processing and modifying the display on the display unit 32.

Additional information from the input devices may also

10   include commands sent to the host 20 for control of the

monitored systems 14-18.

The CDMS 10 was developed by the inventors using the

C programming language and the Open GL graphics library.   It

was implemented on Silicon Graphics hardware, and may run on

15   other UNIX and PC work stations.   It should be understood,

however, that any graphical user interface operating system

could form the backbone for this system.

Figure 4 is a screen display from the CDMS 10 in

accordance with a preferred embodiment of the present

20   invention.   The invention will be described in detail using

an embodiment that is adapted to the task of monitoring a

plurality of spacecraft.   It will be appreciated that this

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application is one of many in which the teachings of the
present invention may be employed.

Data regarding a plurality of spacecraft missions
are depicted in Figure 4 in the form of graphic symbols or
5   objects which are positioned within a three dimensional
virtual universe. The respective dimensions of the virtual
universe correspond to a variety of aspects of the
spacecraft missions 36. Along a first dimension is an
identification of the source of displayed data parameters,
10   such as various spacecraft missions being monitored, labeled
0712, 4487, 4524, etc. Along a second dimension appears
various user-defined categories of data parameters that are
relevant of the application 38, including Communications
(COMM) 38, Power 40, Attitude Control System (ACS) 42,
15   Propulsion (PROP) 44, and SCT 46. Two additional categories
that can be used in most applications are Alarm Log 48 and
User-Defined 50. The alarm log records all anomalous data
parameter values until they are acknowledged by the user.
The user-defined grouping allows copies of data values from
20   any combination of data parameter categories to be grouped
together. A third (vertical) dimension corresponds to
certain user-defined alarm limits and state values for each
of the data parameter categories.

The configuration and position of the graphic symbols in Figure 4 convey a extensive amount of information about the current state of the data parameters to the human operator 12 in an easily understandable and instantly

5   recognizable manner, as described below.

Figures 5a and 5b show the start-up screen of the CDMS 10 which displays two windows: an overview window 56 (Figure 5a) and a main window 54 (Figure 5b). The overview window provides the operator with a global view of the

10   entire cyberspace universe. All data parameter information for the missions being monitored is visible in the overview window at all times, thus keeping the operator apprised of all alarm conditions occurring anywhere within the cyberspace universe. The overview window also allows the

15   operator to know the location of the current viewpoint within the main window, as denoted by a green dot 52 that tells the operator, "you are here."

The main window 54 shown in Figure 5b constitutes the primary source of information for the operator. Unlike

20   the overview window that always displays the entire universe, the main window will typically (but not necessarily) display only a subset of the entire universe at any one time. An operator navigates through three-

dimensional cyberspace using a cursor control device included in input devices 34 (such as a mouse or a trackball) to view the data from any desired viewpoint or perspective. This shifting of viewpoint is accomplished

5   using software techniques commonly employed in computer graphics products such as computer aided design (CAD) systems. The particular viewpoint shown in Figure 5b is a perspective view of the cyberspace universe from a position slight above and pulled back from the universe. A top

10   orthogonal view of a representative cyberspace universe is illustrated in window 58 in Figure 6.

       The main window 54 includes a white grid 60 divided into rows and columns to form adjacent grid squares. The rows correspond to different spacecraft missions (e.g.,

15   MAGELLAN, VOYAGER 1, VOYAGER 1) and the columns correspond to user-defines data parameter categories within each mission (ALARMS, SSO FAULT PROTECTION DATA, etc.). These categories are an application specific way of categorizing the data. The white grid 60 corresponds to the baseline or

20   nominal values of the data parameters. A green upper grid 62 is suspended above and in registration with the white grid to represent the flight approved error ceiling -- i.e., the user-defined critical values for the various data

parameters beyond which serious consequences, such as permanent damage to the monitored system, occurs.

The geometric objects within the white grids of the display represent individual spacecraft telemetry data
5   parameters. Each of the data parameters has a number of attributes which are represented. For example, each of three possible shapes — rectangle, diamond, and triangle — indicate a different type of data parameter; analog, digital, and counter, respectively. Depending on the
10 application, these and other graphical shapes may be used to indicate other attributes and qualities about the data parameter represented. The position of an object on the grid can also indicate its functional classification via adjacency to related parameters, if the user elects to group
15 the objects within the grid square in some meaningful way. For example, objects may be grouped by type of subsystem (electrical, hydraulic, mechanical) or by physical location within the system. All data parameters are normalized to allow a diverse mix of data types and units.

20   While viewing the data objects, the operator may dynamically and interactively specify logical groups of parameters for monitoring. Each user-defined grouping (38-46) of parameters defines a parameter category which is

delimited by a separate column in the grid.   The operator

may define categories through the use of configuration

tables or pop-up menus.   Permanent categories such as "Alarm

Log" or "User-Defined" may also be implemented.

5   The User-Defined category 50 is a temporary

collection of data parameters that the operator is likely to

periodically change at various stages during the mission

under consideration.   One example of such a transient usage

of a user-defined grouping would occur when a particular

10   subsystem in one spacecraft (mission) fails or shows some

anomaly.   The operator may then want to group all data

parameters relevant to the problem (even from multiple

categories) and closely monitor those specific parameters

for each mission in the User-Defined column.   In general,

15   anytime a given situation suggests that certain parameters

demand close attention, the operator can easily place those

parameters temporarily into the User-Defined column.   Hence

parameters which have not reached an alarm or critical state

can be closely monitored during a critical period.   The

20   Alarm Log category is a redundant collection of all alarms

presently occurring in the mission, without regard to

particular data parameter categories.

In this interactive environment of three dimensional graphical objects in cyberspace, the operator can quickly comprehend the full range of information contained in the telemetry data by looking at combinations of shape, color,

5   position, and behavior of geometric objects.

Anomalous data parameter states --*i.e.* alarm conditions-- are immediately visible to the viewer through the color and behavior of the objects. Two types of alarms are employed in this embodiment of the cyberspace system:

10   limit alarms and trend alarms. A limit alarm occurs when the value of a parameter is outside a predefined pair of high and low limits. For example, a limit alarm is activated when one of the following situations occur: (i) an analog value falls outside of its predefined nominal range;

15   (ii) the bit state of a digital parameter does not correspond to a predefined state; or (iii) the counter value of an ASCII data parameter does not correspond to a predefined value.

Two levels of limit alarms are used: warning

20   (preferably yellow) and critical (preferably red). Figures 4, 5a-b show these objects. Objects are displayed in the default color, white, to indicate that the parameter it represents is in its normal state. Objects are displayed

yellow or red to indicate whether the parameter is in a

warning limit alarm state (yellow), or a critical limit

alarm state (red). Figures 4 and 5a-5b also show that

during warning or critical states, the graphical object

5   rises or elevates, to a height above the nominal grid. This

height is proportional to how far the parameter has exceeded

the limit. This provides a graphic indication of the

severity of the alarm. The heights to which the objects

rise are normalized so that the objects always remain

10   positioned between the lower and upper grids, inclusive. At

the same time that the object rises, a bar or pole extends

from to object to the lower grid. This pole serves to

assist the user in estimating the distance that the object

has risen. Since the length of the pole is proportional to

15   the absolute value of the data parameter.

The change in color of an object serves to increase

the visibility of the alarm state. As clearly illustrated

in Figure 5a, this is very useful when viewing objects from

an overhead perspective where the length of the pole below

20   the object may be obscured. In such cases only the color is

available to indicate the presence and severity of the

alarm. A user can recognize that an alarm is active by an

object's color, and can easily change perspective to a side

view to clearly see the height of the object and associated pole.

As shown in Figures 4 and 5a-5b, objects in the "Alarms" category (equivalently, "Alarm Log") do not rise

5   above the normal grid when they enter an alarm state. This is preferred because if these alarm objects were elevated as in other columns, it would produce a display that was too dense with elevated objects for a user to easily intuit meaning from height.

10   If the pole for a data object reaches the upper grid 62 it means that a threshold level of severity of the alarm situation has been reached; for example, it may mean that an unrecoverable error has occurred. When this happens, the color of the corresponding square in the green upper grid 62

15   changes from green to red. The object will remain the same color and shape but will now be encircled by a red square superimposed over that region in the green upper grid 62. This provides the operator with a dramatic indication that a system error has occurred which may need immediate

20   attention. When a yellow object reaches the upper grid it will change to red and begin rising from the lower grid at a level proportionate to its data parameter value.

Rather than depending on the current value of a data

parameter, a trend alarm is based on the rate of change in a

parameter value over time that indicates some kind of

pattern. If the rate of change of a parameter exceeds some

5   predefined limit over a predefined period of time, then the

CDMS 10 triggers a trend alarm for that parameter. A trend

alarm may be triggered when a data value steadily increases

or decreases during a specified time range. Or, the trend

alarm may be triggered when the rate of change for a data

10   parameter has exceeded a predefined limit. For example, if

a fire starts in a spacecraft a temperature sensor may show

an unusually rapid increase in temperature. This rapid rate

of increase will likely trigger a trend alarm well before

the temperature value reaches an alarm level. This gives

15   extra time to respond to the fire and mitigate the damage.

The CDMS 10 currently uses two different techniques

for detecting trend alarms. The first trending technique

tracks the continual increase or decrease of the data

parameter value over a user specified time interval in which

20   a warning or critical alarm will occur. For example, a user

may specify (in the mission database) that a critical alarm

should occur if spacecraft cabin pressure decreases for more

than 8 seconds, because this may indicate a cabin leak as opposed to normal pressure fluctuations.

The second trend alarm involves tracking the rate of change over time: if the rate change of a parameter exceeds

5   some predefined limit over a specified period of time, then the parameter triggers a trend alarm. For example, a rapid non-transitory drop in a battery voltage may suggest a short circuit rather than normal electrical loads. Depending on the system's objectives, a variety of other trending

10   techniques may also be used. The CMDS 10 performs trend analysis in real-time.

Both of these types of trend alarms can assume one of two levels of severity, each of which is represented through a unique data abstraction. If the CDMS 10

15   determines that the trend alarm is less severe (a "warning level" trend alarm), the graphical object associated with that parameter will appear to spin on the screen display. If the alarm is more severe (a "critical level" trend alarm), the object will repeatedly flash between different

20   levels of brightness.

In any given spacecraft mission, a particular data parameter may experience a limit alarm and a trend alarm concurrently. As noted above, a limit alarm and a trend

alarm may each occur in one of two severities -- a limit

alarm may be either warning level (yellow) or critical level

(red) and a trend alarm may be either warning level

(spinning) or critical level (flashing). A preferred

5   embodiment of the CDMS 10 employs the unique combinations of

graphical techniques identified in Table I to represent each

of nine potential combinations of alarm states.

TABLE I

	No Trend Alarm	Warning Trend Alarm	Critical Trend Alarm
No Limit Alarm	white not spinning not flashing	brown spinning not flashing	brown not spinning flashing
Warning Limit Alarm	yellow not spinning not flashing	yellow spinning not flashing	yellow not spinning flashing
Critical Limit Alarm	red not spinning flashing	red spinning not flashing	red not spinning flashing

If a trend alarm occurs while the object already is

in a limit alarm state, the color of the object remains the

same as for the existing limit alarm (i.e., either red or

yellow). If, on the other hand, the object is not in a
limit alarm state, it turns from its nominal white color to
brown when only a trend alarm is triggered. Hence a brown
object immediately tells the user that a trend alarm, but no
5   limit alarm, is active. This use of color, spinning, and
flashing makes possible the unambiguous display of all
possible combinations of limit and trend alarms in a single
object.

Operators familiar with the CMDS 10 will be able to
10   immediately assess which of the 9 different conditions exist
for each parameter. As demonstrated by Figure 4, several
hundred data parameters are easily visible at the same time.
This means that the operator can quickly assess thousands of
possible conditions at a glance. Also, more serious
15   conditions receive more prominent displays.

Furthermore, as indicated by Figure 4, more distant
grid lines converge into a distant virtual background space.
This compresses the more distant data representations into a
smaller portion of the screen space. Regardless of the user
20   viewpoint, when moving through this virtual space, the data
of greater interest is displayed closer and larger than data
of lesser interest which is displayed smaller and farther
away. This distance can continue indefinitely without any

theoretical limit.   Hence, at extreme virtual distances

objects in the background will be so small that the user may

not be able to ascertain much more than the existence of an

alarm status.   The user will then need to move his virtual

5   viewpoint much closer in order to determine exactly which

parameter is in an alarm state.

By shrinking less relevant data representations, the

user is able to effect a continuously variable choice of how

much detail of the various regions of data are displayed at

10   a given moment.   At the same time, the user can maintain an

overall view of the entire data field.   Since there is no

theoretical limit on how far the grids and objects may

extend into the virtual distance, the present invention

makes it possible to monitor a seemingly limitless amount of

15   data at a given time.   For example, upper and lower grids 60

and 62 can extend indefinitely in all directions into

virtual space.   Multiple sets, or arrays, of such grids can

be displayed on a single screen as viewed from a very large

virtual distance.   To effectively monitor such extremely

20   fine-grained displays may require increasing the visibility

of the representation of alarm states because such distant

objects will be extremely small.   In contrast, prior

display and monitoring systems do not provide this intuitive

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and qualitative display of such potentially large amounts of data and would require much more screen space and multiple screens to communicate this much information.

An operator may learn additional information about
5   parameters that are in alarm (*i.e.*, beyond the information that is already graphically represented) by clicking on the data object of interest.   This action causes a pop-up window 64 to appear below the main window as shown in Figure 7. The pop-up window contains text information concerning the
10 chosen parameter and all other parameters contained within the same parameter category.   As shown in the more detailed view of the pop up window 64 in Figure 8, each row corresponds to a data parameter.   Detailed information includes the data parameter mnemonic, data type,
15 description, time of receipt, floating point value, data value as received, and alarm limits.   Of this information, only a limited amount of information (such as data type, data value and alarm limits) can be obtained from the 3D display 54; and this information is represented
20 qualitatively rather than quantitatively.   The detailed numeric information is only needed in unusual circumstances and therefore is not included in the 3D display 54.

Some of the information in the pop up window 64 is similar to what has been traditionally available in text-based displays: parameter name, time of last update, engineering unit value or data number, and type of alarm.

5   Other information available in the pop up window 64 relates to new types of alarms associated with various types of trend analysis. Still further information such as the warning and critical limits of the trend algorithms may be available in the pop-up window 64. Text-bound displays

10   would require an operator to view a different screen for each of possible several hundred objects to glean the equivalent information that is available at a glance using the CDMS 10.

The default amount of information that is displayed

15   in both the graphic windows (*i.e.*, the main 54 and overview 56 windows) and in the pop up text windows 64 is user-selectable based on operator expertise and preferences. The default configuration can be dynamically adjusted by the operator during monitoring operations to reflect changing

20   needs. As shown in Figure 6, for example, the operator may configure the system to display only two of the three potentially available missions or to add a desired number of additional missions. Configuring the display involves

deleting or adding mission database to or from the data directory.

The CDMS 10 also may be used for off-line for non-real-time analysis. Historical data files can be replayed

5 and trend data that has been saved to a database can be displayed. Other features (available in real-time or non real-time mode) allow the display of conventional plots or trend data, suppression of nominal parameter values, suppression of alarm notification for user-specified time

10 intervals, and movement of data objects to any grid-square location chosen by the operator. Suppression of alarms can be done by clicking on the desired data parameter and entering a time unit the suppression is deactivated (as shown in Figure 9). The suppression of the object is

15 conveyed visually (as shown in Figure 10) by turning the object blue. The system automatically detects when the time expires and turns the object back to its original state. This feature can be used for data parameters which are known by the operator or analyst to be anomalous. Organization of

20 data parameters is achieved by selecting the object to move and clicking on the desired area in the grid square where the object will be placed.

The highly visual look and feel of the CDMS 10 may be complemented with the use of speech output to communicate key alarm and parameter identification information to the operator without requiring the reading of text or the

5   viewing of graphic objects. A high-quality audio system is preferably used to digitize and edit key words and phrases. When an operator clicks on an object representing a data parameter or when an alarm occurs, the CDMS 10 joins appropriate words and phrases to deliver a voice alarm

10   (i.e., a spoken message) to the operator indicating the identity of the parameter, the type of alarm (trend or limit) and its severity. When whole words are digitized the resulting speech has a smooth and natural sound. If a more flexible vocabulary is required other speech synthesis

15   methods such as phoneme-based speech synthesis may be used. When a particular data parameter (e.g., E-1234) is in a warning state, the system may say "Parameter E-1234 is in warning." To alert the operator of multiple alarms, the system may say "Four critical alarms have been detected,"

20   thereby informing the operator of the number and severity of alarms occurring.

The CDMS 10 also may be enhanced by providing a speech recognition capability. Efficient pattern matching

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algorithms can be used to accurately identify commands

spoken by the operator. Standard techniques may be used in

which the operator's speech is filtered into frequency bands

that are further subdivided and compared with previously

5   digitized samples used to "train" the software.

Other features which may be used in other

embodiments of the CDMS 10 include the following:

(i) The system may be configured to automatically

dial the operator's telephone pager number by means of a

10   modem 29 whenever an alarm condition occurs, thus informing

the operator that the monitoring system requires attention.

As a result, the operator need not be physically present at

the monitoring system site at all times. Any standard

telephone paging device will suffice for this purpose. The

15   paging feature may be enabled by entering the pager number

into a text-field of the parameter table.

(ii) The system may employ plotting capabilities

which may be used to plot data parameter objects against

real time, historical averages; and summary data, such as,

20   minimum, mean, maximum, standard deviation, *etc.* The

operator may enable plotting through a point-and-click menu.

Any conventional plotting hardware may be used.

(iii) Output data from the system may be printed in either ASCII or Postscript format.

(iv) The system may provide an extensive and user-friendly on-line help system that guides the operator in a
5   clear and succinct step by step format. This may be implemented using a hypertext browser such as the one employed in NETSCAPE.

The implementation of cyberspace representation is highly generic --that is, it is applicable to a wide variety
10   of applications in which varying data is monitored. This enables it to be used for a wide variety of simultaneous data streams and/or missions. Other applications include sensor data from industrial plants, time varying financial data (*i.e.*, stock or securities prices), monitored medical
15   data *i.e.*, blood pressure, heart rate, *etc.*, from large numbers of intensive care patients or other hospital patients). In addition, the cyberspace architecture enables the various modules that comprise the system to be distributed over a network, if desired.

20   Figure 11 shows a flowchart of a preferred embodiment of the method of the cyberspace data monitoring system of the present invention. The process of the invention begins with the generating of a display of a

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three-dimensional cyberspace universe including upper and

lower grids as shown in block 66.   Next, in block 68 objects

representing data parameters are arranged in predetermined

locations based on data categories in the lower grid.   The

5   system configures each object in a predefined geometric

shape based on data parameter type.   As shown in block 72,

the system determines all current object alarm states.   As

shown in block 74, the system displays all objects with no

alarm states in the color white.   The system displays

10   objects with only trend alarms active in the color brown, as

shown in block 76.   All objects with a warning trend alarm

are displayed spinning, as shown in block 78.   The system

then displays all objects with critical alarm trends

flashing, as shown in block 80.   All objects with warning

15   limit alarms are displayed yellow and elevated to a

proportional amount by a yellow pole as in block 82.   All

objects with critical alarm limits are colored red and

displayed elevated to a proportional level by a red pole as

in block 84.

20   As shown in block 86, when a critical alarm reaches

a highly severe state, as indicated by reaching the level of

the upper grid, the upper grid square encircling the object

is highlighted in red.   In decision block 90 the system

determines whether a user input is present. If so, the

system determines, if this user input is a request to modify

the viewpoint, as shown in decision block 94. If not,

decision block 90 directs the process to decision block 92.

5   If the user input is a request to modify the viewpoint, the

viewpoint is altered in a manner which expands approaching

regions and shrinks receding regions of the display

proportionately. If a user input to modify the viewpoint is

not present, as determined in decision block 94, the process

10   proceeds to decision block 98. Also, once the process

completes the step shown in block 96, the process proceeds

to decision block 98, where it is determined whether an

input is received to display more information regarding an

object. If so, the status screen 56 is displayed, as shown

15   in block 100. If not, the process proceeds to decision

block 102, which is reached also after decision block 100 is

performed.

Decision block 102 shows the step of determining

whether a user input is a request to modify user-defined

20   categories. If so, the objects requested are rearranged

into the user-defined category in step 104. The process

then proceeds to block 92; this is also the destination if

decision block 102 determined there was no input to modify

the user- defined category. Block 92 determines whether a

new alarm condition exists anywhere in the display and, if

so, directs the process back to step 72 to update all of the

alarm conditions. If not, the process proceeds to block 106

5   where it is determined whether there is a new user input.

If so, the process proceeds back to block 94 to process this

user input. Otherwise, the process proceeds to block 106

where it is determined whether there is a stop command, and

if not, the process returns to decision block 92. If there

10 is a stop command the process ends.

The invention includes various computer programs

implementing the techniques of the present invention. Some

of these functions may be implemented in hardware or

software, or a combination of both. However, preferably,

15 the invention is implemented in computer programs executing

on programmable computers such as host computer 20 shown in

Figure 3. Program code is applied to input data to perform

the functions described herein and generate output

information. The output information is applied to one or

20 more output devices such as the display unit 32, in known

fashion.

Each program is preferably implemented in a high

level procedural or object oriented programming language to

communicate with a computer system. However, the programs can be implemented in assembly or machine language, if desired. In any case, the language may be compiled or interpreted language.

5   Each such computer program is preferably stored on storage media or device (e.g. ROM or magnetic diskette), readable by a general or special purpose programmable computer, for configuring and operating the computer when the storage media or device is read by the computer to

10   perform the procedures described herein. The inventive system may also be considered to be implemented as a computer-readable storage medium, configured with a computer program, where the storage medium so configured causes a computer to operate in a specific and predefined manner to

15   perform the functions described herein.

Although the invention has been described in detail, it should be understood that various changes, substitutions and alterations can be made without departing from the teachings thereof. For example, two-dimensional planes and

20   landmarks may be represented by ways other than grids, such as by solid objects. More than two grids may be employed, and many different shapes, colors and movements, may be used to represent data, data trends and data conditions.

All such modifications are intended to be encompassed within the following claims.